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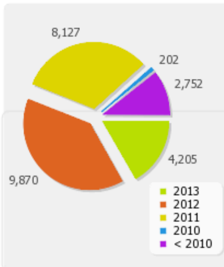

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INVESTIGATION ON SOUND ABSORPTION COEFFICIENT OF NATURAL PADDY FIBERS

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ABSTRACT
The use of synthetic materials as acoustic absorbers is still applied extensively in building industry. These non-biodegradable materials do not only cause pollution to the environment, but also contribute significantly in increasing the CO_2 causing the effect of global warming. Therefore researchers have now driven their attentions to find sustainable and eco-friendly materials to be an alternative sound absorber. This paper discusses the use of natural fibers from dried paddy straw as a fibrous acoustic material. Since this is one of common natural waste materials found across South East Asia, the usage will also minimize the production cost. A panel sound absorber from paddy straw is fabricated and its acoustic properties are investigated through experiment. Good acoustic performance is found particularly above 2 kHz and is comparable against that from the classical synthetic absorber.

Keywords: natural fibres, waste materials, absorption coefficient, sustainable, acoustic performance

1. INTRODUCTION

Over the past decades, acoustic control in building has improved significantly. As progress in technology has enhanced the control of sound quality of a room interior, it is also important to balance the development and application of the advanced materials with the responsibility for the environment. Hence, researchers are becoming interested in natural or renewable materials instead of using synthetic non-renewable materials. According to Asdrubali (2006), these synthetic materials such as foam glass contribute greater Global Warning Potential (GWP; denoted as kg CO_2 equivalent) compared to the natural material such as the coconut fiber. Natural fibers are bio-degradable, non-abrasive, abundance and have less health and safety risks while handling and processing (Zulkifli *et al.*, 2010). These are also found to be low-cost in production compared to that of the mineral based synthetic materials. Most importantly, natural fibers are sustainable, i.e. a resource to keep produce for the needs of present without affecting the future needs (Asdrubali, 2007).

Several works have been published to investigate the performance of natural fibers as the acoustic absorber. D'alessandro and Pispola (2005) worked on a sound absorbing panel made of *Kenaf* fibers. The sample was tested in a reverberation chamber. Good acoustic performance is found at frequency range between 1-5 kHz with the average absorption coefficient of 0.8. Coir fibers are found to be a good acoustic absorber when the fibers were compressed into sheet. Single layer of coir sheet shows good absorption coefficient at mid to high frequencies. Low frequency performance improves when the panel consists of multiple layers (Nor *et al.*, 2004). Zulkifli *et al.* (2009) and Fouladi *et al.* (2010) then utilized the coir panel with perforated facing, thickness, air gap which giving effect at lower frequency and high frequency performance. Ersoy and Kucuk (2009) investigated the tea-leaf fibers and compared the acoustic performance with that of the woven textile cloth. It shows that sound absorption of six layers of the cloth are slightly equivalent to 1 cm thick tea-leaf fibers at frequency range between 500 Hz to 3000 Hz. Lindawati *et al.* (2010) studied the acoustic properties of *Arenga Pinnata* fibers. A 40 mm thickness of fibers shows good acoustic performance from 2-5 kHz. Comparisons are also made with other natural fibers namely coir and palm oil fibers. The *Arenga Pinnata* shows good absorption coefficient above 2 kHz, better than the coir fibers, but slightly lower than palm oil fibers at the average value of 0.7. Most recently, the acoustic properties of straw and reed have been investigated by Oldham *et al.* (2011). These straw and reeds are cut into short lengths and are arranged by facing the cut-end to the incident sound. The absorption coefficient of this arrangement is found around 0.9 for the straw and 0.7 for the reed between 1-5 kHz. Fibres from paddy straw is one of the natural fibres that abundantly available in South East Asia. Since the last decade, it is commonly used for many applications such as roof, rope, animal foods and mat. However, investigation on its capability to be an acoustic material is lacking. According to the authors' knowledge, the most recent related work was done by Yang *et al.* (2003) which utilized the paddy straw aiming at overcoming the lack of solid woods in wood-industry. The paddy straws were cut and were mixed with wood particle using urea–formaldehyde adhesive as the binder to form a solid composite insulation board. The average absorption coefficient is found at 0.5 between 1-8 kHz. As a solid panel, a good strength property is required and this involves mixing with other materials which in consequence reduces the acoustic performance.

This paper proposes the paddy straw fibres to be a facing panel of sound absorber rather than as a solid strong panel. The panel can therefore be applied as distributed facing panels on the wall where necessary to control sound quality in a room. It is found that the sound absorption improves with greater absorption coefficient above 1.5 kHz. The following sections discuss the fabrication process and the experiment conducted in this study.

2. MATERIAL PREPARATION AND FABRICATION

Construction of paddy straw fibers into a sound absorber sample is divided into two stages, namely the pre-treatment stage and fabrication stage. The flow chart of the process is shown in Figure 1. In the pre-treatment stage, the raw materials were cut into 1 to 3 mm length as shown in Figure 2. They were then sundried for 1 week and were again heated in the oven at 115^0C for 10 minutes.

In the fabrication stage, the raw materials were mixed with different composition of binders, blowing agent and additives. These are carboxymethyl cellulose (CMC), gypsum, water (H_2O) and aluminium oxide (Al_2O_3). The amount of ingredient was adjusted to gain optimum strength of bonding. Each ingredient was then scaled and noted for future references. The mixture was then compressed using hydraulic presser at 10 bars in a specially fabricated mould to obtain a round shape. The shaped sample was hardened by heating it in the oven at 115^0C for 30 minutes. The sample constructed has 33 mm diameter as seen in Figure 3.

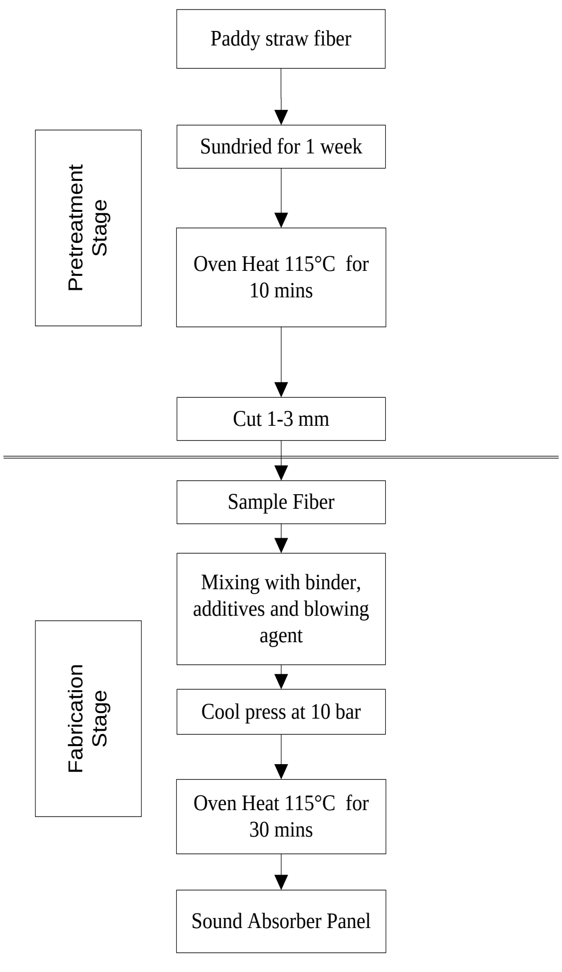


Figure 1 Flow chart of pre-treatment and fabrication processes.

Figure 2 Sample of paddy straw fibers.

Figure 3 The constructed sound absorber sample from the paddy straw fibers.

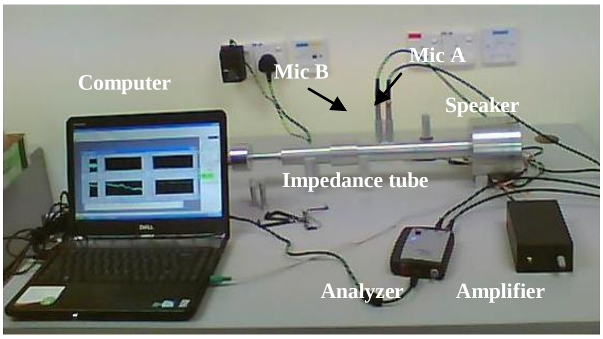
3. SOUND ABSORPTION MEASUREMENT

In this experiment, two samples with different compositions of carboxymethyl cellulose (CMC) were tested. The amount of this binder was varied while preparing these samples. The weight ratio of the CMC as well the blowing agent (gypsum and water) and the filler (Al_2O_3) is shown in Table 1.

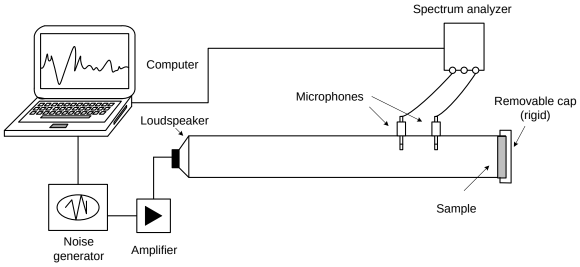
Table 1 The weight ratio of the binder, filler and blowing agent against the paddy straw fibers.

No	Weight Ratio				H_2O
	Paddy	CMC	Al_2O_3	Gypsum	
1.	1	0.05	2	2	Depends
2.	1	0.1	2	2	Depends

The test was performed using a home-made impedance tube by applying two-microphone transfer function method according to ISO 10534-2 (2001) international standards. The sample was placed at the end of the impedance tube and backed by a rigid surface. The acoustic microphones used to measure the sound pressure inside the tube are the ½" Prepolarized free-field microphones (GRAS 40AE) with ½" CCP pre-amplifier (GRAS 26CA). The data acquisition system used was the RT Pro Photon 6.34 analyzer with Dactron software. The signal processing of the raw data was calculated using Matlab software to obtain the absorption coefficient. Figure 4 shows the equipment used and the experimental setup.



(a)



(b)

Figure 4 (a) Equipment used in the experiment and (b) diagram of the measurement setup.

4. RESULTS AND DISCUSSION

Figure 5 show comparison of sound absorption coefficient for samples No. 1 and No. 2 (see Table 1) in one-third octave band frequencies. It can be seen that below 1.5 kHz the absorption coefficient is less than 0.5 which shows poor performance of an acoustic material. However, the performance improves above 2 kHz with average coefficient of roughly between 0.8-0.9.

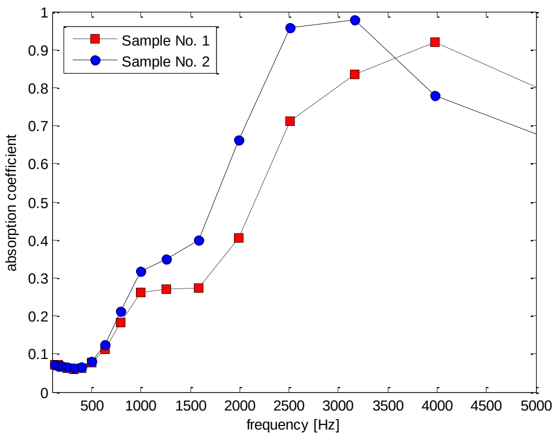


Figure 5 Comparison of the absorption coefficient of fibre panel for sample No. 1 and sample No. 2.

The effect of increasing the CMC can also be seen to shift the acoustic performance towards low frequencies while reducing the absorption at high frequencies. As the binding between the fibres get stronger, the dissipation of sound energy dominates by the whole body vibration of the groups of fibres rather than the localised vibration of the air particle if the bonding is weak. The former mechanism is more effective at low frequencies which then improve the absorption at this frequency range. However, this reduces the absorption at high frequencies. This compromised situation can be adjusted according to specific application.

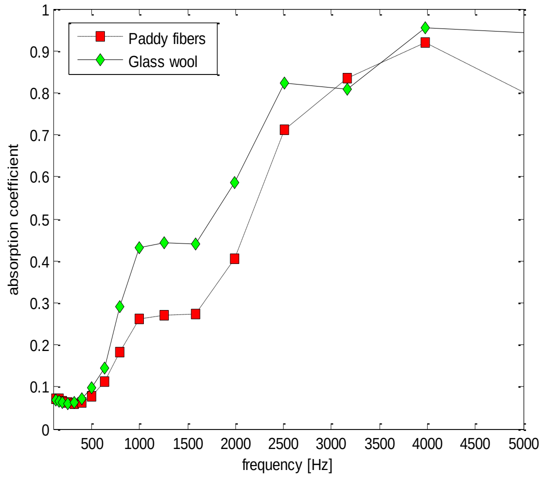


Figure 6 Comparison of absorption coefficient from panels of paddy straw fibres and commercial glass wool.

Figure 6 shows the comparison between of the acoustic performance between the fibre panel (sample No. 1) and the synthetic glass wool panel. It can be seen that the sound absorber panel from the paddy fibres has comparable performance compared to the commercial glass wool absorber which provides the paddy fibres as an alternative sustainable sound absorber.

5. CONCLUSION

Samples of sound absorber panels have been constructed from dried paddy straw fibres. The experiment shows that this natural fibre can be a good alternative sound absorber among many other natural fibres. Good acoustic performance is shown above 1.5 kHz with average absorption coefficient of 0.8.

It is also found that the performance at low frequencies can be increased by increasing the composition of the CMC binder. The effect of varying the composition of other additives (blowing agent and filler) on the acoustic performance as well as the strength of the panel is also of interest. This will be investigated in the future work.

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